Seatbelts

Please refer to this document as follows: **Andersson, M. (2017), Seatbelts, European Road Safety Decision Support System, developed by the H2020 project SafetyCube. Retrieved from www.roadsafety-dss.eu on DD MM YYYY**

Please note: The studies included in this synopses were selected from those identified by a systematic literature search of specific databases (see supporting document). The main criterion for inclusion of studies in this synopsis and the DSS was that each study provides a *quantitative effect estimate*, preferably on the number or severity of crashes or otherwise on road user behaviour that is known to be related to the occurrence or severity of a crash. Therefore, key studies providing qualitative information might not be included in this synopsis.

1 Summary

Andersson, M., July 2017

1.1 COLOUR CODE: GREEN

The 3-point seat belt measure can be qualified as effective, referring to the unanimous and high positive effects regarding prevention of injuries and fatalities during a crash for which this type of occupant safety system is designed.

1.2 KEYWORDS

Seat belt; safety belt; 3-point seat belt; load limiter; LL; force limiter; FL; pretensioner; PT; seat belt reminder; SBR.

1.3 ABSTRACT

Seatbelts are an effective safety countermeasure in road vehicle crashes. The seatbelt restrains the occupant during a crash and reduces the risk of violent contact with vehicle interiors as well as protecting against the risk of ejection from the vehicle. Seatbelts have been proven effective in a global distribution of studies.

1.4 BACKGROUND

1.4.1 How does seat belt usage affect road safety?

The main function of a seatbelt is to reduce the risk of injury of an occupant of a vehicle in a given crash; it restrains the occupant to the vehicle, thereby enabling the occupant to "ride down" (less violently) as they are coupled to the vehicle's deceleration through the restraint system. An unrestrained occupant continues to move at the vehicle's pre-impact speed while the vehicle begins to decelerate as a result of the crash. This uncontrolled occupant motion will result in an uncontrolled occupant impact with the vehicle interior, or in the worst case, be ejected from the vehicle, fully or partially. The seat belt is not intended to affect crash risk.

1.4.2 Definition

Seat belt

Historical view: The first seat belt had two attachment points to the vehicle floor (2-point belt) and fitted across the occupant's pelvis, often used in aeroplanes in the early 1900s. The increasing number of serious and fatally injured people in car crashes initiated the development of the seat belt application in cars. The first car seat belts were installed in 1956 in cars owned by the Swedish electricity producing company Vattenfall[1] in order to reduce work related fatalities and injuries.

Today's state of the art seat belt is a three point design (3-point belt) with a third attachment point on the B-pillar above the occupant's shoulder or sometimes integrated into the seatback. This type of seat belt was developed in the 1950s. The 3-point seat belt was patented in 1951 in the US (by Roger W Griswold and Hugh DeHaven) and in 1958 in Sweden. The Swedish patent was released in 1959. It was mainly developed by engineer Nils Bohlin who had a background in developing catapult

[11] (http://historia.vattenfall.se/sv/entreprenorsskap-och-kreativitet/bilsakerhetsbalte-typ-vattenfall)

seats and belts for the aeroplane manufacturer Saab and was at the time working for the car manufacturer Volvo. The 3-point seat belt was standard equipment for all Volvo cars from the year 1959. Today, the 3-point seat belt is state of the art in most types of motorised vehicles designated for the transport of people.

The 3-point belt consists of one lap belt and one shoulder belt portion, indicating the body regions which are primarily restrained by them. These two body regions are considered to best transfer the load of the crash to the human body. The state of the art seat belt is a single belt design, crossing both the hips and the chest, with attachments at three different locations/points in the vehicle: two at either side of the car occupant's pelvis, so that the lap belt crosses the hips; and one at one of the occupant's shoulders, so that the shoulder belt crosses the chest of the occupant between the shoulder attachment and one of the hip attachments. The seat belt can include various design features and functions that may affect its protective effect. The main ones are presented in the following list.

- Features that reduce slack and enable early coupling between the occupant and the vehicle
    a. Seat belt retractor with Automatic or Emergency Locking functions (enables good trade-off between safety and comfort)
    b. Seat belt pretensioner: the earlier the seat belt is engaged with the human body in a crash event, the better. Seat belt slack is undesirable as it delays this engagement. Slack is created by loosening the fit of the belt (sometimes for comfort reasons) or by compressible volume in the occupant's clothing (e.g. insulation in winter clothing). Slack can be removed by a voluntary tight fit of the seat belt and by a seat belt pretensioner system. There may be one or more pretensioners in a seat belt system. The state of the art is a pretensioner that deploys when a crash occurs. Such systems have the potential to reduce some slack only. There are also more advanced pretensioners that will deploy before a crash is unavoidable and these require a reversible deployment mechanism and more advanced sensors that can predict critical situations. Pretensioners that deploy before the crash may have the potential to pre-position the occupant to a more favourable position from a protection point of view, but thus require powerful actuation systems.
- Seat belt energy absorption
    c. The belt itself, or webbing, is made of woven polyester yarn. Its width is about 50 mm. Its elongation, ranging from about 6 to 12%, is part of the energy absorbing function of the seat belt.
    d. The load limiter is a device that reduces the forces applied to the occupant. The most common types absorb the loads from the crash by breaking or deforming material integrated into the seatbelt.
- The seat belt geometry is usually characterised by the location/position of the effective load bearing anchors at the ends of the belts crossing the occupant's body. The seat belt geometry affects the structures in the human body where the crash loads are applied. Generally, it is preferable to apply the loads to the pelvic bone and to a broad area across the chest/rib cage. An additional shoulder belt may help to distribute the loads and to increase the robustness due the unpredictable nature of crashes. Dual shoulder belts may be realised in different ways, e.g. by two belts routed diagonally and crossing over the chest; one diagonal and one routed over one shoulder like a rucksack shoulder strap; or, both of the shoulder belts attached to the lap belt over the crotch of the occupant. An alternative means of distributing the load is effected by adding an inflatable part to the shoulder belt.

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Seat belt reminder

The main task of the seat belt reminder is to increase the usage rate of the seat belt. Technically, the seat belt reminder system needs a sensor system to detect whether the seat belt is used, an algorithm to determine if the seat belt should be used in the situation at hand, and finally a system to make the occupant aware (usually visual or audio signals) of the need to put on the seatbelt.

1.4.3 Which safety outcomes are affected by the seat belt?

Seat belt effect

The seat belt affects the risk of injury or fatality of vehicle occupants (any type of vehicle and any seat position in the vehicle). Its primary function is to restrain and control the loads applied to the human body. Due to the fact the human body is locally restrained by the seat belts, injuries may occur as an effect of the typical loading. Specifically, injuries in the abdominal area commonly occur if the belt is positioned across the soft tissues of the abdomen instead of the bony part of the pelvis. This is often referred to as seat belt syndrome and/or submarining. It is important to keep in mind that overall the injuries generated by the seat belt are less severe than injuries occurring to unrestrained occupants.

Seat belt effect and crash type

There is also a relation between the seat belt effect and the type of crash. The seat belt affects the movement of the human body mainly in frontal, far side and rear impacts and even, to some extent, in rollovers but less so in near side impacts. However, the focus of this synopsis is frontal impacts.

Seat belt effect and occupant age

Seat belt induced injury frequency is affected by the age of the occupants; chest injuries occur more frequently to elderly occupants, and less frequently to younger occupants (Ekambaram, Frampton, & Bartlett, 2015).

1.4.4 How is the effect of the seat belt studied?

The effect of the seat belt is studied mainly by comparing the injury outcomes in crashes for restrained vs. unrestrained occupants when all other crash circumstances are identical or similar. The actual measuring of the seat belt effect is complicated by the possibility of controlling for all other factors that have an effect on the same outcome, e.g. access to the actual crash pulse, the pre-crash dynamics of the car that affect the actual position of the seat belt across the occupant's body, the characteristics of the person involved in the crash (typically gender and age to approximate human tissue characteristics), and other crash specific characteristics. To measure the effects of various seat belt design features, such as specific load limiter levels, pretensioner performance levels, and specific locations of attachments relative to the occupant, even more details are required to be recorded/documented for each crash case; this type of data is not present in national or international crash databases. Such detailed studies may be conducted at the individual car manufacturers, but are rarely published in detail.

The effects of various seat belt design features are mainly studied by comparing different belt configurations (including non-use) in either physical or simulated test environments; these comparisons are aimed at predicting the actual real-life effects by presenting reductions in ATD measures, e.g. chest deflection or chest acceleration. Such studies were not the focus for this synopsis, only studies assessing real-world injury reduction benefits were included.
Case studies that describe injury patterns and outcomes were the preferred source of information on the effectiveness of seat belts.

1.5 OVERVIEW OF RESULTS

Seat belt benefit

Two meta-analyses have been identified and coded covering the effect of use vs. non-use of seat belts on occupants of cars (Hoye & Elvik, The handbook of Road Safety Measures, Norwegian (online) version, 2015), (Hoye, How would increasing seat belt use affect the number of killed or seriously injured light vehicle occupants? 2016). Since there was a partial overlap of included studies in between the two, the main focus here was the most recent one (also the most extensive meta-analysis). The main conclusions were that the seat belt reduces (use vs. non-use) the risk of being killed or severely injured by 60% among front seat occupants and by 44% among rear seat occupants. Also, seat belt usage among rear seat occupants drastically affects the safety of belted front seat occupants; unbelted rear seat occupants can double the fatality and injury rate for belted front seat occupants, while belted rear seat occupants have little or no influence.

Another study explored the real-world benefit in injury reduction. There was also one meta-analysis that covered occupants of heavy vehicles (trucks and buses).

Seat belt reminder

No studies assessing the benefit of seat belt reminders fulfilling the search criteria were identified.

2 Scientific overview

2.1 LITERATURE REVIEW

2.1.1 Overview results

(Hoye, How would increasing seat belt use affect the number of killed or seriously injured light vehicle occupants? 2016): For the meta-analysis log-odds method effect estimates are calculated as odds ratios for different groups of light vehicle occupants. The odds ratios express the odds of a fatality (or injury) in a crash for a belted occupant against the odds of a fatality (or injury) for an unbelted occupant. The summary effects were calculated with a random effects model (to take heterogeneity into account, unless too few estimates were available) with weighted odds ratios, the statistical weight being a function of the standard error of the odds ratios. Heterogeneity was tested with Cochran's Q-statistic. The criteria for inclusion in the meta-analysis were: the effect of seat belt use on injury or fatality risk is presented with sufficient information for calculation of confidence intervals (t-value or standard deviation); light vehicles, and; multivariate methods or matched pairs of occupants to control for confounding factors. Results for lap belts were not included. The results indicate that seat belts are more effective for drivers than for front seat passengers, and more effective for front seat occupants than for rear seat occupants. These differences were statistically significant. The results also indicate that the effectiveness may have improved over time. The results were tested for publication and outlier bias, neither of which seem to affect the results by more than a few percent; the effect for driver fatalities may be somewhat overestimated. Unbelted rear seat occupants effectively doubled the fatality and injury risk among belted front seat occupants, and had more or less no effect on unbelted front seat occupants. The meta-analysis study concludes that seat belts reduce the risk of being killed or severely injured by 60% among front seat occupants and by 44% among rear seat occupants.

Table 1 **Description of coded studies designs / sample frames - Compatibility (WP6)**

Author(s), Year	Sample and study design	Method of analysis	Outcome indicator	Main result
Hoye, How would increasing seat belt use affect the number of killed or seriously injured light vehicle occupants? (2016)	Meta-analysis based on 30 studies from Spain, France and the US.	Meta-analysis of log-odds. Random effects model.	Effect on fatality Effect on injury	The meta-analysis study concludes that seat belts reduce the risk of being killed or severely injured by 60% among front seat occupants and by 44% among rear seat occupants.
Abay, Paleti & Bhat (2013)	Sample from the Danish nationwide crash database: Two-vehicle car crashes; two-driver crashes (only the driver as the occupant in each vehicle);	Multivariate ordered-response probit model	Injury severity according to the KABCO scale	

	occurring between (and including) 2002 and 2008. The final sample for analysis included 5077 crashes involving 10,154 drivers.			
Hoye, 2013	Meta-analysis based on 5 studies (from the US, Pakistan) looking at effect of seat belt usage among professional drivers of HGV (buses and trucks)	Estimate based on random effects meta-analysis	Percent change in injury risk for HGV drivers	The meta-analysis study concludes that seat belt usage vs. non-usage significantly reduces the risk of severe injury among HGV drivers by 42 % (CI: -61 – -14%) while the percent change in fatality is not significant (-47, CI: -73 – 5%). No effect estimate for bus occupants provided.
Hoye, Elvik, 2015	Meta-analysis based on 16 studies from Europe and the US.	Meta-analysis (fixed and random effects). Cross-sectional and case-control studies.		

2.2 SYNTHESIS OF LITERATURE REVIEW - METHODS AND RESULTS

The various studies presented data that were not numerically comparable. Table 2 shows the benefit for seatbelts.

Table 2 **Overview of results of coded studies - compatibility (WP6)**

Author(s) Year	Country Period covered	Study type	Dependent/ outcome variable	Risk factor	Effect for road safety	Main outcome - description
Hoye, How would increasing seat belt use affect the number of killed or seriously injured light vehicle occupants? (2016)	Spain: 1993-2000 France: 1996-2000 US: 1975-2008	Meta-analysis	Percent change of odds of **fatality** for belted vs. unbelted occupants	Front seat occupant	↑	The meta-analysis study concludes that seat belts reduce the risk of being killed or severely injured by 60% among front seat occupants and by 44% among rear seat occupants. Unbelted rear seat occupants about double the fatality and injury rate for belted front seat occupants.
				Rear seat occupant	↑	
				Belted front seat occupant AND unbelted occupant in the rear seat	↓	
			Percent change of odds of **injury** for belted vs. unbelted occupants	Occupant in any seat	↑	
				Belted front seat occupant AND unbelted occupant in the rear seat	↓	
Abay, Paleti & Bhat (2013)	Denmark Crashes during the years between	Multivariate ordered-response probit			↓	

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	(and including) 2002 and 2008.					

2.2.1 Summary of results

The results of all studies are conclusive that seatbelts are effective countermeasures for occupants in the event of a crash. The results are consistent in all studies and regions and confirm that the results are transferable.

3 Supporting document

3.1 MEASURE ACCORDING TO WP6 TAXONOMY – SEATBELT

3.1.1 Identifying relevant studies

Database: Scopus via Chalmers Library
Query date: 2017-02-24

Query string	***No. of hits***
TITLE-ABS-KEY(effectiveness OR (injury AND severity) OR (benefit AND analysis)) AND TITLE-ABS-KEY ((seat AND belt) OR seatbelt OR safetybelt) AND ALL(death OR injury OR fatal) AND DOCTYPE(ar OR re) AND PUBYEAR > 2012	171
TITLE-ABS-KEY (effectiveness OR (injury AND severity) OR (benefit AND analys)) AND TITLE-ABS-KEY ((seat AND belt) OR seatbelt OR safetybelt) AND ALL(death OR injury OR fatal) AND ALL(frontal OR head-on) AND DOCTYPE(ar OR re) AND PUBYEAR > 2012	67
TITLE-ABS-KEY (effectiveness OR (injury AND severity) OR (benefit AND analysis)) AND TITLE-ABS-KEY ((seat AND belt) OR seatbelt OR safetybelt) AND ALL(death OR injury OR fatal) AND ALL(frontal OR head-on) AND ALL(real-world OR database OR road OR accident OR crash OR collision) AND DOCTYPE(ar OR re) AND PUBYEAR > 2012	67
TITLE-ABS-KEY (effectiveness OR (injury AND severity) OR (benefit AND analysis)) AND TITLE-ABS-KEY ((seat AND belt) OR seatbelt OR safetybelt) AND ALL(death OR injury OR fatal) AND ALL(frontal OR head-on) AND ALL(real-world OR database OR road OR accident OR crash OR collision) AND ALL(driver OR passenger OR occupant) AND DOCTYPE(ar OR re) AND PUBYEAR > 2012	61
TITLE-ABS-KEY (effectiveness OR (injury AND severity) OR (benefit AND analysis)) AND TITLE-ABS-KEY ((seat AND belt) OR seatbelt OR safetybelt) AND ALL(death OR injury OR fatal) AND ALL(frontal OR head-on) AND ALL(real-world OR database OR road OR accident OR crash OR collision) AND ALL(driver OR passenger OR occupant) AND ALL(car OR van OR SUV OR automobile OR truck OR HGV OR single-unit OR tractor OR trailer OR (heavy AND vehicle)) AND DOCTYPE(ar) AND PUBYEAR > 2012	55
TITLE-ABS-KEY (effectiveness OR (injury AND severity) OR (benefit AND analysis)) AND TITLE-ABS-KEY ((seat AND belt) OR seatbelt OR safetybelt) AND ALL(death OR injury OR fatal) AND ALL(frontal OR head-on) AND ALL(real-world OR database OR road OR accident OR crash OR collision) AND ALL(driver OR passenger OR occupant) AND ALL(car OR van OR SUV OR automobile OR truck OR HGV OR single-unit OR tractor OR trailer OR (heavy AND vehicle)) AND DOCTYPE(ip) AND PUBYEAR > 2012	1
TITLE-ABS-KEY (effectiveness OR (injury AND severity) OR (benefit AND analysis)) AND TITLE-ABS-KEY ((seat AND belt) OR seatbelt OR safetybelt) AND ALL(death OR injury OR fatal) AND ALL(frontal OR head-on) AND ALL(real-world OR database OR road OR accident OR crash OR collision) AND ALL(driver OR passenger OR occupant) AND ALL(car OR van OR SUV OR automobile OR truck OR HGV OR single-unit OR tractor OR trailer OR (heavy	9

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AND vehicle)) AND DOCTYPE(cp) AND PUBYEAR > 2012	
TITLE-ABS-KEY (Seatbelt OR "seat belt") AND TITLE-ABS-KEY (effectiveness OR "use rate" OR "usage rate") TITLE-ABS-KEY (reminder) AND DOCTYPE (ip) OR DOCTYPE(ar)	
TITLE-ABS-KEY (Seatbelt OR "seat belt" OR safetybelt) AND TITLE-ABS-KEY (effectiveness OR benefit) TITLE-ABS-KEY ("load limiter" OR loadlimiter OR "force limiter") AND PUBYEAR > 1999 DOCTYPE (cp) OR DOCTYPE(ar)	19
Total no. of articles for screening:	68

effectiveness AND (real-world OR database) AND (Injury OR fatal) AND ABS((seat AND belt) OR seatbelt OR safetybelt) AND (driver OR passenger OR occupant) AND (frontal OR head-on) AND (collision OR crash OR accident) AND (LIMIT-TO(DOCTYPE,"ir ") OR LIMIT-TO(DOCTYPE,"ar ") OR LIMIT-TO(DOCTYPE,"cp ")) AND (LIMIT-TO(PUBYEAR,2017) OR LIMIT-TO(PUBYEAR,2016) OR LIMIT-TO(PUBYEAR,2015) OR LIMIT-TO(PUBYEAR,2014) OR LIMIT-TO(PUBYEAR,2013)) 21

3.1.2 Screening abstracts and titles

Inclusion criteria	*Exclusion criteria*
	Results based on numerical simulation study
	Results based on sled test with ATDs or PHMS
	In-depth case reporting
	Statistical modelling and analysis not included
	Sample size <=30
	Sample includes unbelted occupants exclusively
	Studies on outcome in side impact only
	Studies on outcome in rear impact only
	Study focusing alcohol impairment
	Studies on outcome in rollover only

3.1.3 Full text eligibility

Full- text review for inclusion/exclusion decision.

No. of papers remaining for full-text review	***26***

No. of eligible papers after full-text review	***26***
No. of full-texts that could not be obtained	***4***
Reference lists examined	***Yes/No***

The most important article among those selected for full-text review is the meta-analysis (Hoye, How would increasing seat belt use affect the number of killed or seriously injured light vehicle occupants? 2016). One of the articles is included in the meta-analysis and was excluded for that reason (Bose, Arregui-Dalmases, Sanchez-Molina, Velazquez-Ameijide, & Crandall, 2013).

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References for full-text review	Specific reason for exclusion (unless selected for coding)
Abay, K. A., Paleti, R., & Bhat, C. R. (2013). The joint analysis of injury severity of drivers in two-vehicle crashes accommodating seat belt use endogeneity. *Transportation Research Part B: Methodological*, *50*. https://doi.org/10.1016/j.trb.2013.01.007	Excluded: Study does not include calculation of seat belt effectiveness
Bjurlin, M. A., Fantus, R. J., Fantus, R. J., Mellett, M. M., & Villines, D. (2014). The impact of seat belts and airbags on high grade renal injuries and nephrectomy rate in motor vehicle collisions. *Journal of Urology*, *192*(4). https://doi.org/10.1016/j.juro.2014.04.093	Excluded: Study does not include calculation of seat belt effectiveness.
Bose, D., Arregui-Dalmases, C., Sanchez-Molina, D., Velazquez-Ameijide, J., & Crandall, J. (2013). Increased risk of driver fatality due to unrestrained rear-seat passengers in severe frontal crashes. *Accident Analysis and Prevention*, *53*. https://doi.org/10.1016/j.aap.2012.11.031	Excluded: Article included in meta-analysis that is selected for the DSS
Castro, M., Paleti, R., & Bhat, C. R. (2013). A spatial generalized ordered response model to examine highway crash injury severity. *Accident Analysis and Prevention*, *52*. https://doi.org/10.1016/j.aap.2012.12.009	Excluded: Study does not include calculation of seat belt effectiveness.
Chen, R., & Gabler, H. C. (2014). Risk of thoracic injury from direct steering wheel impact in frontal crashes. *Journal of Trauma and Acute Care Surgery*, *76*(6). https://doi.org/10.1097/TA.0000000000000222	Excluded: pdf not available
El-Menyar, A., Consunji, R., Asim, M., Abdelrahman, H., Zarour, A., Parchani, A., Al-Thani, H. (2016). Underutilization of occupant restraint systems in motor vehicle injury crashes: A quantitative analysis from Qatar. *Traffic Injury Prevention*, *17*(3). https://doi.org/10.1080/15389588.2015.1069820	Excluded: Study based on non-European or non-US data (Qatar)
Goetzke, F., & Islam, S. (2015). Determinants of seat belt use: A regression analysis with FARS data corrected for self-selection. *Journal of Safety Research*, *55*. https://doi.org/10.1016/j.jsr.2015.07.004	Excluded: Study does not include calculation of seat belt effectiveness
Hitosugi, M., & Matsui, Y. (2015). Safety of the Japanese K-Car in a Real-World Low-Severity Frontal Collision. *Traffic Injury Prevention*, *16*(1). https://doi.org/10.1080/15389588.2014.885649	Excluded: Study does not include calculation of seat belt effectiveness
Hitosugi, M., Takaso, M., Matsumoto, A., Koseki, T., Furukawa, S., & Mizuno, K. (2016). Analysis of injuries requiring ophthalmological check-ups because of frontal vehicle collisions. *Romanian Journal of Legal Medicine*, *24*(4). https://doi.org/10.4323/rjlm.2016.261	Excluded: Study does not include calculation of seat belt effectiveness
Hwang, K., & Kim, J. H. (2015). Effect of Restraining Devices on Eye Injury in Motor Vehicle Collisions. *The Journal of Craniofacial Surgery*, *26*(1), 220–221. https://doi.org/10.1097/SCS.0000000000001261	Excluded: pdf not available
Høye, A. (2016). How would increasing seat belt use affect the number of killed or seriously injured light vehicle occupants? *Accident Analysis & Prevention*, *88*, 175–186. https://doi.org/10.1016/j.aap.2015.12.022	Selected for coding CODED
Li, P., Ma, C., Dong, Y., Li, H., & Zhang, J. (2016). AIS 3+ Thoracic Injuries Among Drivers in Real-World Motor Vehicle Frontal	Excluded: Data analysis method is not adequate

Crashes: The Effect of Impact Direction, Impact Location and Status of Seat Belt. In *2016 Eighth International Conference on Measuring Technology and Mechatronics Automation (ICMTMA)* (pp. 71–76). IEEE. https://doi.org/10.1109/ICMTMA.2016.26	for coding (no multivariate analysis or paired comparison)
Mitchell, R. J., Bambach, M. R., & Toson, B. (2015). Injury risk for matched front and rear seat car passengers by injury severity and crash type: An exploratory study. *Accident Analysis & Prevention*, *82*, 171–179. https://doi.org/10.1016/j.aap.2015.05.023	Excluded: No detailed information on seat belt usage.
Parenteau, C. S., & Viano, D. C. (2014). Spinal Fracture-Dislocations and Spinal Cord Injuries in Motor Vehicle Crashes. *Traffic Injury Prevention*, *15*(7). https://doi.org/10.1080/15389588.2013.867434	Excluded: Data analysis method is not adequate for coding (no multivariate analysis or equal, no confidence intervals or tests of results).
Parenteau, C. S., Zhang, P., Holcombe, S., Kohoyda-Inglis, C., & Wang, S. C. (2014). Can Anatomical Morphomic Variables Help Predict Abdominal Injury Rates in Frontal Vehicle Crashes? *Traffic Injury Prevention*, *15*(6). https://doi.org/10.1080/15389588.2013.852665	Excluded: Study does not include calculation of seat belt effectiveness Can be referred to in synopsis.
Patel, V., Griffin, R., Eberhardt, A. W., & McGwin Jr., G. (2013). The association between knee airbag deployment and knee-thigh-hip fracture injury risk in motor vehicle collisions: A matched cohort study. *Accident Analysis and Prevention*, *50*. https://doi.org/10.1016/j.aap.2012.07.023	Excluded: Study does not include calculation of seat belt effectiveness
Poplin, G. S., McMurry, T. L., Forman, J. L., Hartka, T., Park, G., Shaw, G.,Crandall, J. (2015). Nature and etiology of hollow-organ abdominal injuries in frontal crashes. *Accident Analysis and Prevention*, *78*. https://doi.org/10.1016/j.aap.2015.02.015	Excluded: Study does not include calculation of seat belt effectiveness Can be referred to in synopsis.
Rao, R. D., Berry, C. A., Yoganandan, N., & Agarwal, A. (2014). Occupant and crash characteristics in thoracic and lumbar spine injuries resulting from motor vehicle collisions. *The Spine Journal*, *14*(10), 2355–2365. https://doi.org/10.1016/j.spinee.2014.01.038	Excluded: Study does not include calculation of seat belt effectiveness
Rao, R. D., Sobel, E. H., Berry, C. A., & Yoganandan, N. (2016). Occupant and Crash Characteristics of Elderly Subjects With Thoracic and Lumbar Spine Injuries After Motor Vehicle Collisions. *SPINE*, *41*(1), 32–38. https://doi.org/10.1097/BRS.0000000000001079	Excluded: pdf not available
Rice, T. M., & Zhu, M. (2014). Driver obesity and the risk of fatal injury during traffic collisions. *Emergency Medicine Journal*, *31*(1). https://doi.org/10.1136/emermed-2012-201859	Excluded: Study does not include calculation of seat belt effectiveness
Ryb, G., Dischinger, P., Kerns, T., Burch, C., Rabin, J., & Ho, S. (2013). Changes in the severity and injury sources of thoracic aorta injuries due to vehicular crashes. In *Annals of Advances in Automotive Medicine* (Vol. 57).	Excluded: Study does not include calculation of seat belt effectiveness Can be referred to in synopsis.

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Stewart, T. C., McClafferty, K., Shkrum, M., Comeau, J.-L., Gilliland, J., & Fraser, D. D. (2013). A comparison of injuries, crashes, and outcomes for pediatric rear occupants in traffic motor vehicle collisions. *Journal of Trauma and Acute Care Surgery*, *74*(2). https://doi.org/10.1097/TA.0b013e31827d606c	Excluded: pdf not available
Sznol, J. A., Koru-Sengul, T., Graygo, J., Murakhovsky, D., Bahouth, G., & Schulman, C. I. (2016). Etiology of fatal thoracic aortic injuries: Secondary data analysis. *Traffic Injury Prevention*, *17*(2), 209–216. https://doi.org/10.1080/15389588.2015.1067805	Excluded: Study does not include calculation of seat belt effectiveness
Viano, D. C., & Parenteau, C. S. (2015). Concussion, Diffuse Axonal Injury, and AIS4+ Head Injury in Motor Vehicle Crashes. *Traffic Injury Prevention*, *16*(8), 747–753. https://doi.org/10.1080/15389588.2015.1013188	Excluded: Study does not include calculation of seat belt effectiveness
Yasmin, S., Eluru, N., Bhat, C. R., & Tay, R. (2014). A latent segmentation based generalized ordered logit model to examine factors influencing driver injury severity. *Analytic Methods in Accident Research*, *1*. https://doi.org/10.1016/j.amar.2013.10.002	Excluded: Study does not include calculation of seat belt effectiveness
Zhang, P., Parenteau, C., Wang, L., Holcombe, S., Kohoyda-Inglis, C., Sullivan, J., & Wang, S. (2013). Prediction of thoracic injury severity in frontal impacts by selected anatomical morphomic variables through model-averaged logistic regression approach. *Accident Analysis and Prevention*, *60*. https://doi.org/10.1016/j.aap.2013.08.020	Excluded: Study does not include calculation of seat belt effectiveness
Lie, A., Kullgren, A., Krafft, M., Tingvall, C. (2008) Intelligent Seatbelt Reminders: Do They Change Driver Seat Belt Use in Europe. *Traffic Injury Prevention* 9(5) 446-449. http://dx.doi.org/10.1080/15389580802149690	Excluded: few observations; the study does not control for other covariates like gender, age or socio-economic, which are known predictors of seat belt use.

4 Bibliography

Abay, K. A., Paleti, R., & Bhat, C. R. (2013). The joint analysis of injury severity of drivers in two-vehicle crashes accommodating seat belt use endogeneity. *Transportation Research Part B, 50*, 74-89.

Bose, D., Arregui-Dalmases, C., Sanchez-Molina, D., Velazquez-Ameijide, J., & Crandall, J. (2013). *Accident Analysis and Prevention*. doi:10.1016/j.aap.2012.11.031

Ekambaram, K., Frampton, R., & Bartlett, L. (2015). Improving the chest protection of elderly occupants in frontal crashes using SMART load limiters. *Traffic Injury Prevention, 16*, 77-86.

EKAMBARAM, K., FRAMPTON, R., & BARTLETT, L. (2015). Improving the Chest Protection of Elderly Occupants in Frontal Crashes Using SMART Load Limiters. *Traffic Injury Prevention, 16*, 77-86.

Hoye, A. (2016). How would increasing seat belt use affect the number of killed or seriously injured light vehicle occupants? *Accident Analysis & Prevention, 88*, 175–186. Retrieved from http://dx.doi.org/10.1016/j.aap.2015.12.022

Hoye, A., & Elvik, R. (2015). *The handbook of Road Safety Measures, Norwegian (online) version.* Retrieved from tsh.toi.no: http://tsh.toi.no/index.html?22457

Parenteau, C. S., & Viano, D. C. (2014). Spinal Fracture-Dislocations and Spinal Cord Injuries in Motor Vehicle Crashes. *Traffic Injury Prevention, 15*(7), 694-700.